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**DEPARTMENT OF DEFENCE  
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AERODYNAMICS NOTE 392

**A PROPOSAL FOR AERODYNAMICALLY ACTUATED  
SELF STREAMLINING SUBSONIC WIND TUNNEL WALLS**

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by

N. POLLOCK



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A PROPOSAL FOR AERODYNAMICALLY ACTUATED  
SELF STREAMLINING SUBSONIC WIND TUNNEL WALLS

(10)

by

N. POLLOCK



SUMMARY

An arrangement is described which ensures that solid flexible two dimensional subsonic wind tunnel walls will automatically and continuously assume a shape approximating an unconstrained streamline under the action of a model pressure field. Such a tunnel wall would minimize wall interference.

Each wall consists of a streamwise tensioned membrane with a series of pressure tappings. These pressure tappings communicate with a number of flexible bellows which apply appropriate local forces to the membrane.

Methods covering the extension of this concept to a three dimensional configuration are also discussed.

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*ABSTRACT*

An arrangement is described which ensures that solid flexible two dimensional subsonic tunnel walls will automatically and continuously assume a shape approximating an unconstrained streamline under the action of a model pressure field. Such a tunnel wall would minimize wall interference.

Each wall consists of a streamwise tensioned membrane with a series of pressure tappings. These pressure tappings communicate with a number of flexible bellows which apply appropriate local forces to the membrane.

Methods covering the extension of this concept to a three dimensional configuration are also discussed.

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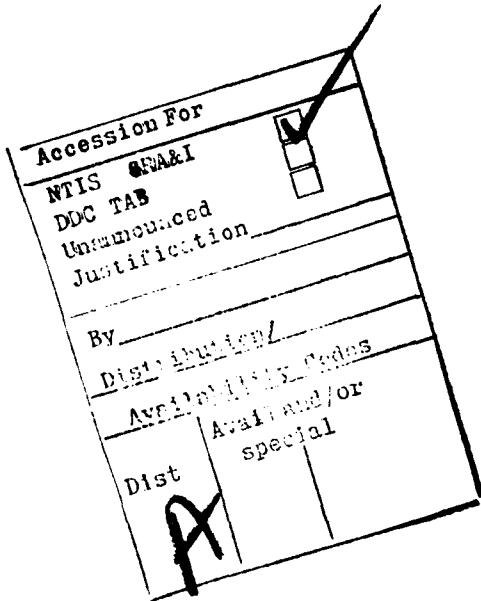
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### **DISTRIBUTION**



### *NOTATION*

<i>a</i>	Distance between wall pressure tappings (Fig. 1)
<i>c</i>	Length of wall pushing bellows (Fig. 1).
<i>C<sub>p</sub></i>	Pressure coefficient = $(P - P_0)/( \frac{1}{2} \rho U_0^2 )$ .
<i>F</i>	Force exerted on wall membrane by bellows.
<i>h</i>	Tunnel semi-height.
<i>k</i>	Strength of vortex.
<i>l</i>	Length of tunnel wall.
<i>m</i>	Strength of source.
<i>M</i>	Mach number.
<i>P</i>	Static pressure.
<i>R</i>	Reaction of wall on end supports.
<i>T</i>	Wall tension.
<i>U</i>	Flow velocity.
<i>x</i>	Coordinate along tunnel wall.
<i>y</i>	Coordinate perpendicular to wall.
$\beta$	$\sqrt{1 - M^2}$
$\mu$	Strength of doublet.
$\rho$	Density.
Subscripts	
<i>o</i>	Free stream conditions.
<i>w</i>	Condition on flow side of wall.
<i>b</i>	Conditions behind wall.

## 1. INTRODUCTION

It is well known that due to the presence of the tunnel walls, the flow about a model in a wind tunnel is not identical to the flow which would exist in an unbounded stream (such as is assumed to exist in flight). This wall interference causes aerodynamic forces measured in a tunnel to differ from those experienced in free flight. The magnitude of the wall interference, for a particular test condition, depends on the relative sizes of the model and tunnel and the nature of the tunnel walls. Since the 1930's it has been common for theoretical and empirical corrections to be applied to tunnel data to account for the effects of wall interference. When the interference is small, corrections to the tunnel velocity and model angle of attack are sufficient. For larger interference, streamwise gradients of flow velocity and downwash cannot be neglected. When these gradients become significant the flow over the model becomes basically different from the free flight flow and simple corrections to tunnel data cease to be satisfactory.

Low speed wind tunnels have for many years successfully used solid wall or open jet test sections and theoretical interference prediction techniques<sup>1</sup>. Unfortunately solid wall and open jet test sections are basically unsuitable for transonic testing<sup>2</sup>. During the late 1940's ventilated test sections were developed for transonic tunnels and they have been used very extensively since that time. Interference theory has been developed for ventilated test sections<sup>1,3</sup> but due to uncertainties concerning the wall boundary conditions it has not been as satisfactory as the equivalent theory applied to solid wall and open jet tunnels.

Despite the use of ventilated walls and theoretical corrections the maximum permissible model blockage ratio for transonic tunnel testing is of the order of 1%. Since Reynolds number is a vitally important parameter in many transonic tests, this low usable blockage ratio has led to the use of very large and expensive wind tunnels. For many years it has been evident that any significant reduction in wall interference would lead to a considerable reduction in tunnel size and cost for a given Reynolds number capability. The main impetus for tunnel interference reduction has come from transonic testing but it is recognized that any significant development will also benefit low speed testing.

During 1973 two investigators<sup>4,5</sup> independently published proposals for "Self Correcting" wind tunnels where a computer was to be used to modify the wall conditions during tunnel operation to completely remove the effects of wall interference. Following the original proposals a large body of literature has appeared demonstrating that it is indeed possible, at least in theory, to produce walls which contribute zero interference using only measurements of flow direction and pressure near the wall. The computing power and wall mechanical complexity required is considerable. Self correcting tunnel configurations involving the use of variable porosity<sup>4</sup>, fixed porosity with multiple plenum chambers at different pressures<sup>5</sup> and solid flexible walls<sup>6</sup> have been proposed. Although the conformable wall interference free tunnel concept is applicable to three dimensional testing, the complexity would be great and all the practical implementations to date have been for two-dimensional testing. A number of relatively successful two dimensional tests (see for example Refs 7 and 8) have been carried out and the concept of minimum interference wind tunnels can be considered to be proved in principle. It is interesting to note that flexible solid wall tunnels were used during the early 1940's<sup>9</sup> but were not continued with, presumably due to the development of ventilated walls.

At the present stage of self correcting tunnel development it appears probable that some residual corrections to the measured results will still be required. This raises the question of how to best divide the available computing power between wall modification and residual interference correction. Kemp<sup>10</sup> has proposed what he terms a "Correctable—Interference Wind Tunnel" where the walls are modified to roughly approximate the interference free configuration and corrections calculated from the measured wall flow conditions are applied to the results. The correctable—interference concept has not yet been fully developed but it appears to be an attractive approach to the use of large tunnel blockage ratios without requiring prohibitively complex adjustable walls.

At present the optimum method of setting tunnel walls to approximate the interference free condition has not been established. The most obvious (and most complex) approach is the use of self correcting tunnel technology with a computer controlling multiple plenum chambers or flexible walls. One alternative approach mentioned briefly in Reference 11 is the use of a flexible membrane wall which would hopefully contour itself into an unrestrained streamline shape (and thus cause no interference) when acted on by the model pressure field. Unfortunately elementary considerations of the sign of wall curvature resulting from an applied pressure show that such a wall assumes a shape quite unlike an unconfined flow streamline. A simple membrane wall would also be statically unstable since any local bump would tend to grow under the action of its own pressure field.

In this Note a relatively simple passive wall configuration is proposed which will adopt an approximately streamlined shape in a compressible subsonic stream under the action of the model pressure field. For simplicity a two dimensional embodiment of this concept will be described but the same principle should be applicable to a three dimensional tunnel test section.

## 2. DESCRIPTION OF CONCEPT

A perusal of the linearized equations of motion for compressible subsonic flow<sup>12</sup> suggests that the streamline curvature at any point in an unbounded flow will be approximately proportional to the local pressure coefficient and to  $\beta$ . The streamline curvature will be concave towards regions of low pressure. In supersonic flow the streamline slope will be proportional to the local pressure coefficient and to  $\beta$ .

The difference between the subsonic and supersonic streamline behaviour is sufficiently fundamental to make it unlikely that any simple passive self-adaptive wall will be able to cope with both types of flow. A preliminary approach to the design of a self adapting supersonic wall has recently been published<sup>13</sup>. In this note the design of basically subsonic walls (with the possibility of a small supersonic region) is discussed since this is the problem of greatest current importance.

The physical arrangement of the proposed self adaptive subsonic wind tunnel wall is shown in Figure 1. A flexible membrane forming the actual flow boundary is subject to a streamwise tension ( $T$ ) which is made inversely proportional to  $\beta$ . In the two dimensional configuration considered here the edges of the membrane wall are assumed to slide without friction on the adjacent pair of walls. The membrane wall is equipped with a number of equally spaced pressure tappings which communicate with flexible bellows via rigid connecting tubes. The total bellows area to wall area ratio ( $c/a$  in Fig. 1) must exceed 1·0 and the highest possible value should be used to maximize the wall tension and thus minimize the bulging between pressure tappings (See Section 5). With the two layer bellows arrangement shown in Figure 1  $c/a$  ratios approaching 2·0 can be achieved. With more complex bellows arrangements more desirable higher values of  $c/a$  can be obtained. The volume behind the wall membrane and containing the flexible bellows is subject to a backing pressure ( $P_b$ ) which is adjusted so that the sum of the wall force components in the  $y$  direction at  $x = 0$  and  $x = l$  is equal to zero. From Figure 1 it is evident that this condition can be met using two simple angle transducers and altering  $P_b$  until

$$\frac{dy}{dx} \Big|_{x=0} - \frac{dy}{dx} \Big|_{x=l} = 0$$

The arrangement described in this proposal has equally spaced pressure tappings and a constant bellows size along the entire length of the wall. This was done for simplicity of exposition. In practice, to minimise manufacturing difficulties, the tappings and bellows would probably be spaced closely near the model and more widely away from the model location.

## 3. COMPUTATION OF WALL BEHAVIOUR

Considering the behaviour of the wall when subject to a pressure field  $P_w(x)$ . The  $y$  equilibrium equation of the membrane (Fig. 1) can be written:

$$\int_0^l (P_w - P_b) dx = c \sum_{j=0}^{i-n} (P_{wj} - P_b) = Ry|_{x=0} + Ry|_{x=l} \quad (1)$$

but

$$Ry|_{x=0} + Ry|_{x=l} = 0 \quad (2)$$

From (1) and (2) and re-arranging (remembering  $P_b = \text{constant}$ )

$$Pb = \left[ \int_0^l P_w dx - c \sum_{j=0}^{i-n} P_{wj} \right] / (l - nb) \quad (3)$$

Taking moments about  $x = 0$

$$Ry|_{x=l} = \left[ \int_0^l x(P_w - P_b) dx - c \sum_{j=0}^{i-n} x_j (P_{wj} - P_b) \right] / l \quad (4)$$

$Pb$ ,  $Ry|_{x=0}$  and  $Ry|_{x=l}$  can be calculated from equations (2), (3) and (4).

The wall membrane slope at  $x = 0$  is given by:

$$\frac{dy}{dx}|_{x=0} = \frac{Ry|_{x=0}}{T} \quad (5)$$

The relationship between the membrane slopes at any two points  $x_1$  and  $x_2$  which do not have a pressure tapping between them is:

$$\frac{dy}{dx}|_{x=x_2} = \frac{dy}{dx}|_{x=x_1} + \frac{1}{T} \int_{x_1}^{x_2} (P_w - P_b) dx \quad (6)$$

At each pressure tapping there is a slope discontinuity due to the concentrated load applied to the membrane. This slope change can be written as:

$$\frac{dy}{dx}|_2 - \frac{dy}{dx}|_1 = \frac{F}{T} \quad (7)$$

where stations 1 and 2 are immediately before and after the point of application of the concentrated bellows force  $F$ . Using equations (5), (6) and (7) it is possible to compute the wall slope  $dy/dx(x)$  over the range  $x = 0$  to  $x = l$ . By integrating these slope data the wall deflection  $y(x)$  can be calculated.

In Reference 9 approximate expressions for unconfined streamline shapes and pressure distributions in compressible subsonic flow around a doublet, vortex and source are presented. Expressions for the pressure distribution on a solid plane wall and the shape of a constant pressure open jet boundary are also included. Since a real model can be considered as a combination of doublets, vortices and sources these singularities provided valuable test cases.

Re-arranging the expressions in Reference 9 it can be shown that:

(a) For unconfined potential flow.

Doublet	$\frac{2\pi U h}{\mu} \cdot y = \frac{(x/h)^2}{(x/h)^2 + \beta^2}$
	$\frac{\pi U h^2}{\mu} \cdot Cp = \frac{(x/h)^2 - \beta^2}{((x/h)^2 + \beta^2)^2}$
Vortex	$\frac{2\pi U}{k} \cdot y = \frac{\beta}{2} \ln \left( 1 + \left( \frac{1}{\beta} \right)^2 \left( \frac{x}{h} \right)^2 \right)$
	$\frac{\pi U h}{k} \cdot Cp = \frac{\beta}{(x/h)^2 + \beta^2}$

$$\text{Source} \quad \frac{2\pi U}{m} \cdot y = \beta \operatorname{Arctan} \left( \frac{x}{\beta h} \right)$$

$$\frac{\pi U h}{m} \cdot Cp = \frac{-(x/h)}{(x/h)^2 + \beta^2}$$

(b) For plane straight walls  $2h$  apart.

$$\text{Doublet} \quad \frac{\pi U h^2}{\mu} \cdot Cp = \frac{-\pi^2}{4\beta^2} \operatorname{Sech}^2 \frac{\pi x}{2\beta h}$$

$$\text{Vortex} \quad \frac{\pi U h}{k} \cdot Cp = \frac{-\pi}{2\beta} \operatorname{Sech} \frac{\pi x}{2\beta h}$$

$$\text{Source} \quad \frac{\pi U h}{m} \cdot Cp = \frac{-\pi}{2\beta} \left( \operatorname{Tanh} \frac{\pi x}{2\beta h} + 1 \right)$$

(c) For a free jet of height  $2h$ .

$$\text{Doublet} \quad \frac{2\pi U h}{\mu} \cdot y = \frac{\pi}{2} \left( \operatorname{Sech} \frac{\pi x}{2\beta h} - 1 \right)$$

$$\text{Vortex} \quad \frac{2\pi U}{k} \cdot y = \frac{-\pi x}{2h} - \beta \ln \operatorname{Cosh} \frac{\pi x}{2\beta h}$$

$$\text{Source} \quad \frac{2\pi U}{m} \cdot y = \beta \operatorname{gd}^* \left( \frac{\pi x}{2\beta h} \right)$$

Note: In all the above expressions the origin for  $x$  is at the singularity location.

\* gd Stands for Gudermannian function.

#### 4. CALCULATED WALL SHAPES

Two different sets of (mathematical) model walls were used in this investigation. One set was 6 h long (where  $h$  = tunnel semi height) with 30 pressure tappings in each wall. The other set was 4 h long with 20 pressure tappings.  $c/a$  was taken as 1.95 for both walls. All integrations were performed numerically over 300 and 200 intervals for the 6 h and 4 h walls respectively.

##### 4.1 Doublet, Vortex and Source Models

For the initial calculations the 6 h walls were used with the doublet, vortex and source located at their midpoint. The single value of the wall tension which gave the best fit near the model between the computed wall shape and the equivalent unconstrained streamline was determined for  $M \approx 0$  (Figs 2, 3 and 4). In these and other figures the wall shape and streamline shape have been shifted to coincide at  $x = 0$ . This simplifies comparisons and is legitimate since it is equivalent to only a very small change in tunnel height. For the doublet and source the upper and lower conformable walls will both have positive  $y$  directions into the flow. For the vortex one wall will have positive  $y$  into the flow and the other positive  $y$  out of the flow. Further wall shapes were calculated for Mach numbers of 0.8 and 0.95 with the wall tension set at  $1/\beta$  times the zero Mach number value (Figs 5-10).

In Figs 2-10 the boundary shape of an equivalent open jet and the pressure distribution on a pair of plane walls are also presented to show how far they differ from the interference free streamline values. In all cases it is evident that the conformable wall is much closer to the streamline than either a plane wall or an open jet. At this point it should be noted that since the conformable wall does not assume the streamline shape exactly, the pressure distribution acting on the wall will not be exactly the assumed streamline distribution and the final converged wall shape will differ somewhat from that presented here. However some approximate calculations indicate that the final converged wall shape will not differ greatly from the present approximation to the shape.

To investigate the sensitivity of the conformable wall shape to the axial position of the model in the test section, calculations were carried out at  $M = 0.8$  for the doublet, vortex and source located at  $x = 4 h$  from the start of the  $6 h$  walls (Fig. 11). These calculations were carried out using the same wall tension as for the previous cases with the model in the centre of the walls. Comparing Figure 11 with Figures 5, 6 and 7 it can be seen that moving the model away from the centre of the walls does not significantly degrade the agreement between wall and streamline shapes in the vicinity of the model.

Calculations were carried out of wall shapes for the  $4 h$  long walls at  $M = 0.8$  with doublet vortex and source models located at their midpoint (Fig. 12). A different value of wall tension was required for these shorter walls. Comparing Figure 12 with Figures 5, 6 and 7 it is evident that shortening the walls does not degrade the agreement between wall and streamline shapes.

#### 4.2 Aerofoil Model

Although the theoretical streamline shapes and pressure distributions for doublet, vortex and source used in the previous section are very convenient for development purposes, some test cases involving real physical models would be valuable to build confidence in the concept. Unfortunately very few examples of streamline shape and pressure distribution at compressible speeds for real models have ever been published. In Reference 14 two pseudo-viscous transonic theoretical streamlines are presented. These streamlines are 140 mm away from a 127 mm chord,  $6^{\circ}$ , thick, circular arc aerofoil at zero lift, with free stream Mach numbers of 0.91 and 0.95. The calculated conformable wall shapes are compared with the theoretical streamline shapes in Figures 13 and 14. For  $M = 0.91$  (Fig. 13), where only a small supersonic tongue reaches the wall, the agreement is good. As would be expected, at  $M = 0.95$  (Fig. 14) where there is a considerable extent of supersonic flow at the wall the agreement between wall and streamline shapes is not as good. However even in this case the conformable wall would probably contribute less interference than a solid plane wall or an open jet.

### 5. FURTHER DEVELOPMENTS

One of the basic problems with the proposed conformable wall is that the membrane tends to bulge between the pressure tappings under the action of the pressures acting on either side (Fig. 15). This bulging could be reduced by increasing the  $c/a$  ratio with a consequent increase in wall tension. Alternatively the membrane could be arranged to have some beam stiffness with a resulting reduction in the maximum curvature. However wall stiffness has been found to produce inferior agreement with streamline shapes and excessive rigidity should therefore be avoided. Increasing the total number of pressure tappings and bellows also reduces this problem. It should be remembered that the wall boundary layer will "smear over" small scale wall imperfections (as well as altering the effective wall shape to some extent).

The stability of a tunnel fitted with the proposed wall configuration has not been considered in this Note. However it seems reasonable to assume that if the time constant of the wall response was much longer than any of those associated with the tunnel flow, the entire system would be stable. The time constant of the overall wall response could be arbitrarily extended by restricting the flow in the tubes linking the pressure tappings and the bellows. Local instabilities of the membrane between pressure tappings may be a problem and if so a backing of low modulus high hysteresis plastic foam should effect a cure.

The wall design described has fixed test section entry and exit dimensions. For a model with a significant wake (which can be considered as a source in the flow) the agreement between wall shape and streamline shape some distance from the model could be considerably improved if the test section entry or exit dimensions could be varied. It is tentatively suggested that the entry or exit dimensions be varied until the sum of the wall slopes at  $x = 0$  and  $x = l$  is zero. This would only require one additional actuator since the wall slopes at  $x = 0$  and  $x = l$  are already measured for the setting of backing pressure.

To extend the present concept to a three dimensional test section the following suggestions are offered. The tunnel test section should consist of a continuous membrane in the form of a

tube of suitable shape. The membrane should be an anisotropic material with a high axial modulus of elasticity and a low circumferential modulus. The surface of the membrane should be covered with pressure tappings on a fixed grid spacing (the more tappings the better). The bellows connected to the pressure tappings should apply a force along the local normal to the wall. Wall slopes should be measured at a number of points in the test section entry and exit planes with mean values being used for setting the wall backing pressure. A check on the validity of the above suggestions awaits the availability of suitable three dimensional streamline data.

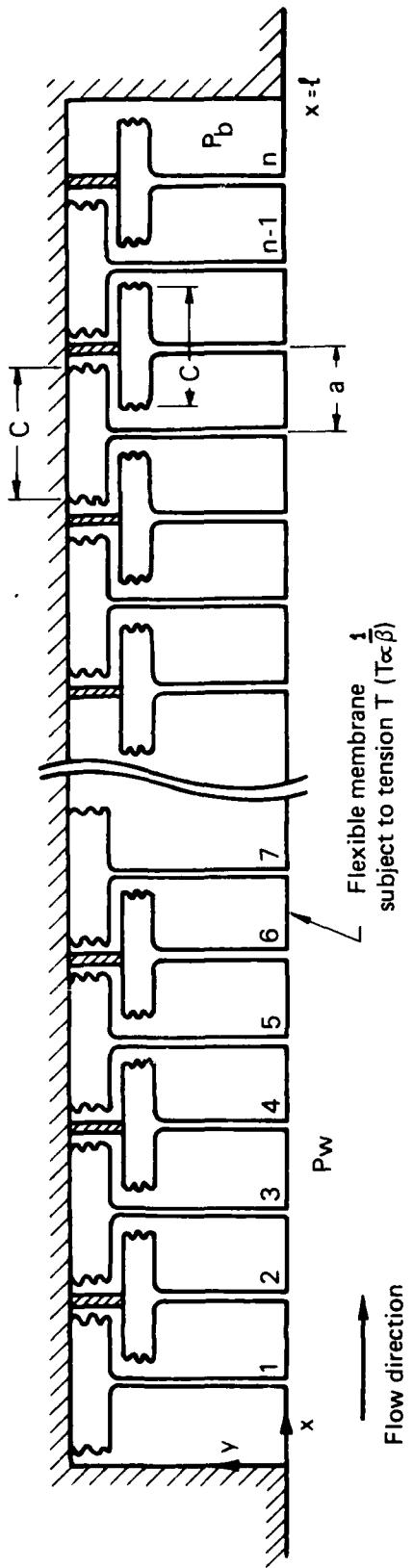
## 6. CONCLUSION

A proposal is presented for a simple conformable two dimensional subsonic wind tunnel wall which would assume a shape approximating an unconstrained streamline under the action of the model pressure field. Such a tunnel wall would contribute very low interference and permit larger models to be used than are currently possible. The proposed configuration basically consists of a tensioned membrane with a series of pressure tappings. These pressure tappings communicate with flexible bellows which apply appropriate local forces to the membrane. Suggestions on the extension of this concept to three dimensional walls are included.

Calculations of wall shape when subject to known streamline pressure distributions confirm that at subsonic and transonic speeds (provided no large supersonic regions reach the wall) the wall assumes a shape approximating that of an unconstrained streamline. These results are very encouraging but a definite proof of the validity of this concept requires more detailed calculations of wall shapes including the influence of the walls on the model and on each other. Such calculations are possible in principle, at least for subsonic flow, and should be carried out as soon as suitable computer codes become available.

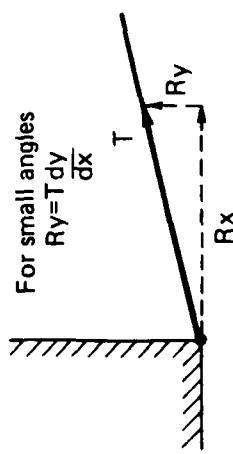
## REFERENCES

1. H. C. Garner, E. W. E. Rogers, W. E. A. Acum and E. C. Maskell—Subsonic Wind Tunnel Wall Corrections. AGARDograph 109, Oct. 1966.
2. B. H. Goethert—Transonic Wind Tunnel Testing. AGARDograph 49. Pergamon Press 1961.
3. M. Pindzola and C. F. Lo—Boundary Interference at Subsonic Speeds in Wind Tunnels with Ventilated Walls. A.E.D.C.-TR 69-47, 1969.
4. A Ferri and P. Baronti—A Method for Transonic Wind-Tunnel Corrections. AIAA Journal Vol. 11, No. 1, Jan. 1973, pp. 63-66.
5. Sears, W. R.—Self Correcting Wind Tunnels. The Sixteenth Lanchester Memorial Lecture of the Royal Aeronautical Society, London, May 1973, and the Aeronautical Journal, Feb. 1974, pp. 80-89.
6. M. J. Goodyer—The Self Streamlining Wind Tunnel. NASA. TM X-72699, August 1975.
7. W. R. Sears—Some Experiences with the Exploitation of Measurements of the Perturbation Field in a Windtunnel to Improve Simulation. AGARD CP-210 Numerical Methods and Windtunnel Testing, Oct. 1976.
8. S. W. D. Wolf and M. J. Goodyer—Self Streamlining Wind Tunnel - Low Speed Testing and Transonic Test Section Design. NASA CR-145257, Oct. 1977.
9. C. N. H. Lock and J. A. Beavan—Tunnel Interference at Compressibility Speeds using the Flexible Walls of the Rectangular High-Speed Tunnel. ARC. R & M 2005, Sept. 1944.
10. W. B. Kemp, Jr.—Towards the Correctable-Interference Transonic Wind Tunnel. AIAA 9th Aerodynamic Testing Conference. Arlington, Texas, June 1976.
11. W. R. Sears, R. J. Vidal, J. C. Erickson and A. Ritter—Interference-Free Wind Tunnel Flows by Adaptive-Wall Technology. ICAS Paper 76-02.
12. H. W. Liepmann and A. E. Puckett—Introduction to Aerodynamics of a Compressible Fluid. John Wiley & Sons. 1948.
13. E. H. Dowell and D. B. Bliss—Wind Tunnel Wall Interference. Part I -A Compliant Wall Supersonic Wind Tunnel. AFOSR-TR-78-1057, 1978.
14. P. Baronti, A. Ferri and T. Weeks—Analysis of Wall Modifications in a Transonic Wind Tunnel. ATL-TR-181, or AFOSR-TR-73-1900, 1973.

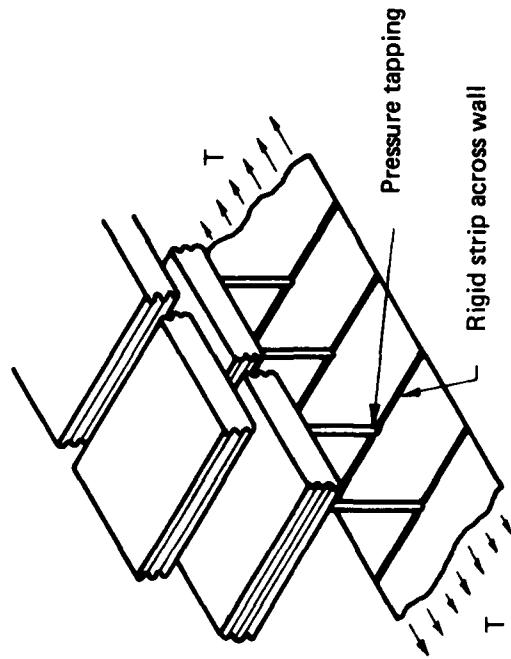


$$P_b \text{ adjusted so that} \\ R_y|_{x=0} + R_y|_{x=L} = 0$$

Edges of wall seal to and slide against adjacent plane walls



Detail of membrane attachment



Detail of short section of wall

FIG. 1 ARRANGEMENT OF PROPOSED SELF STREAMLINING WALL

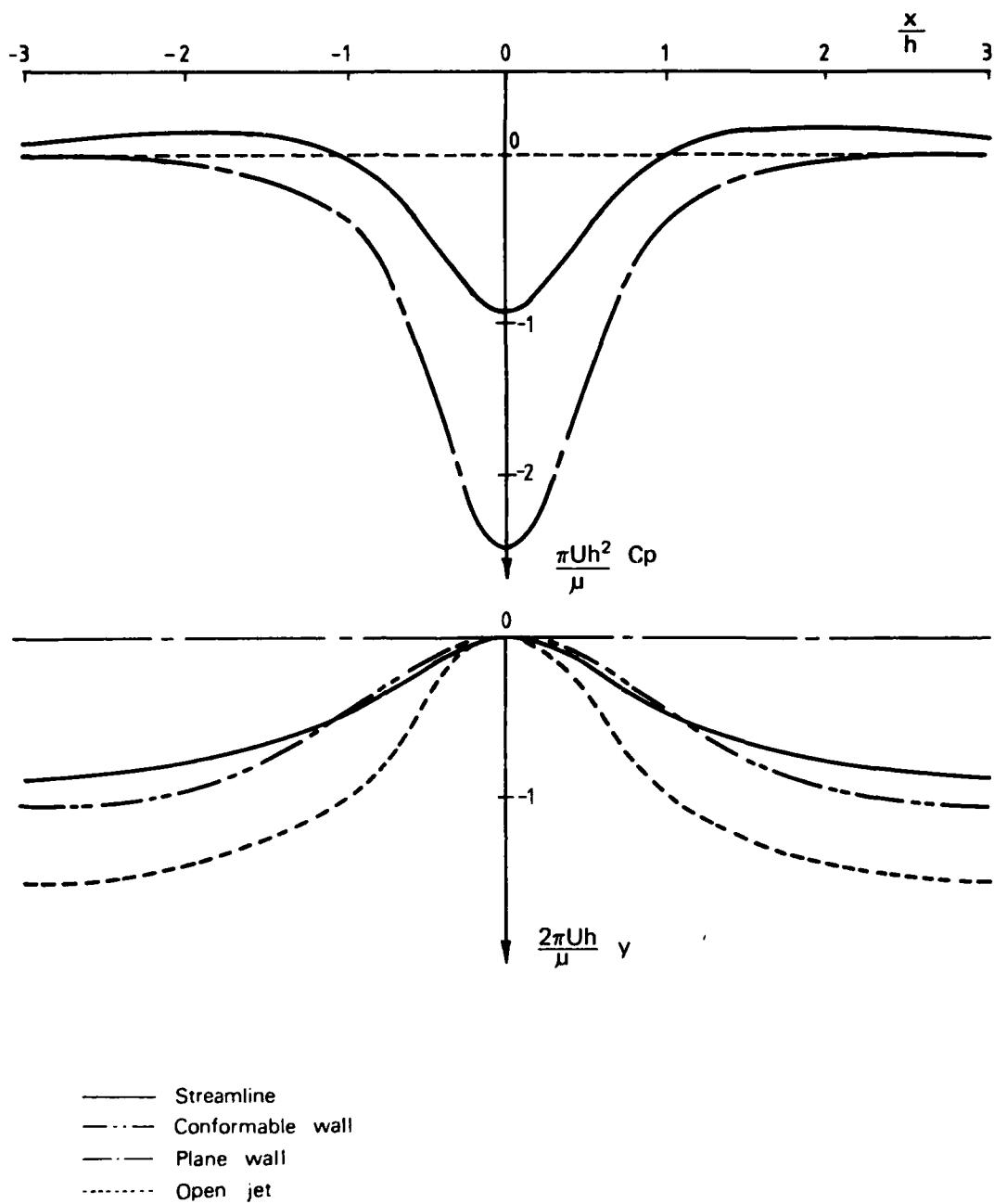
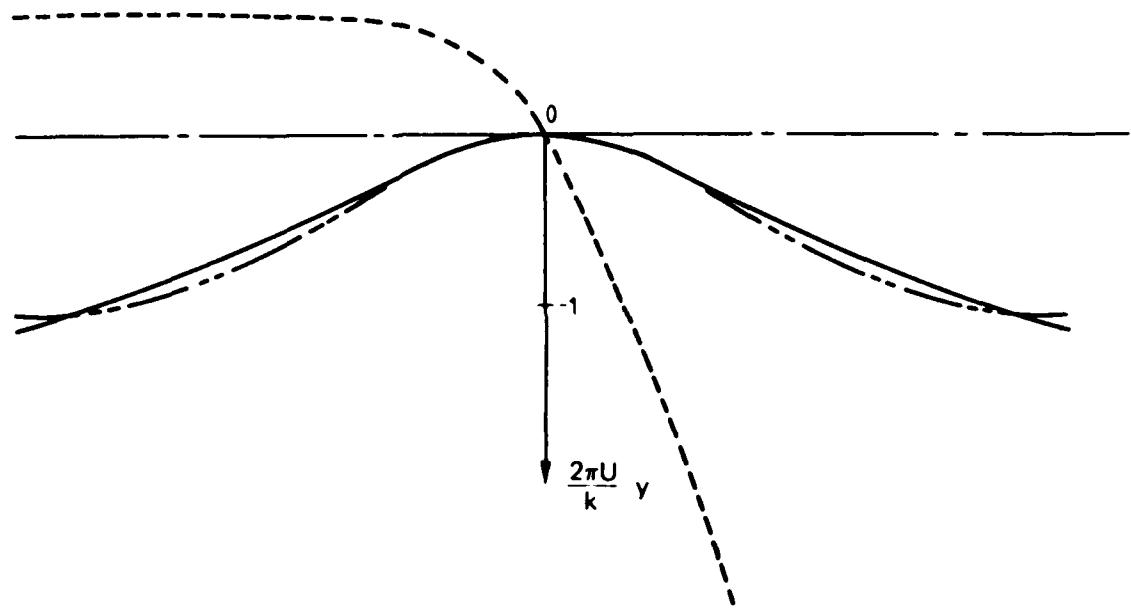
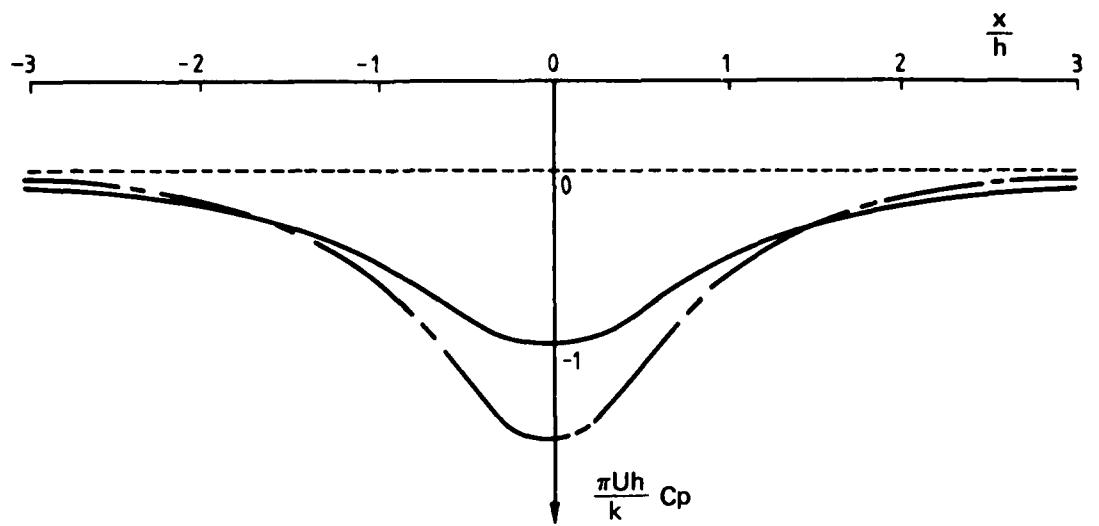
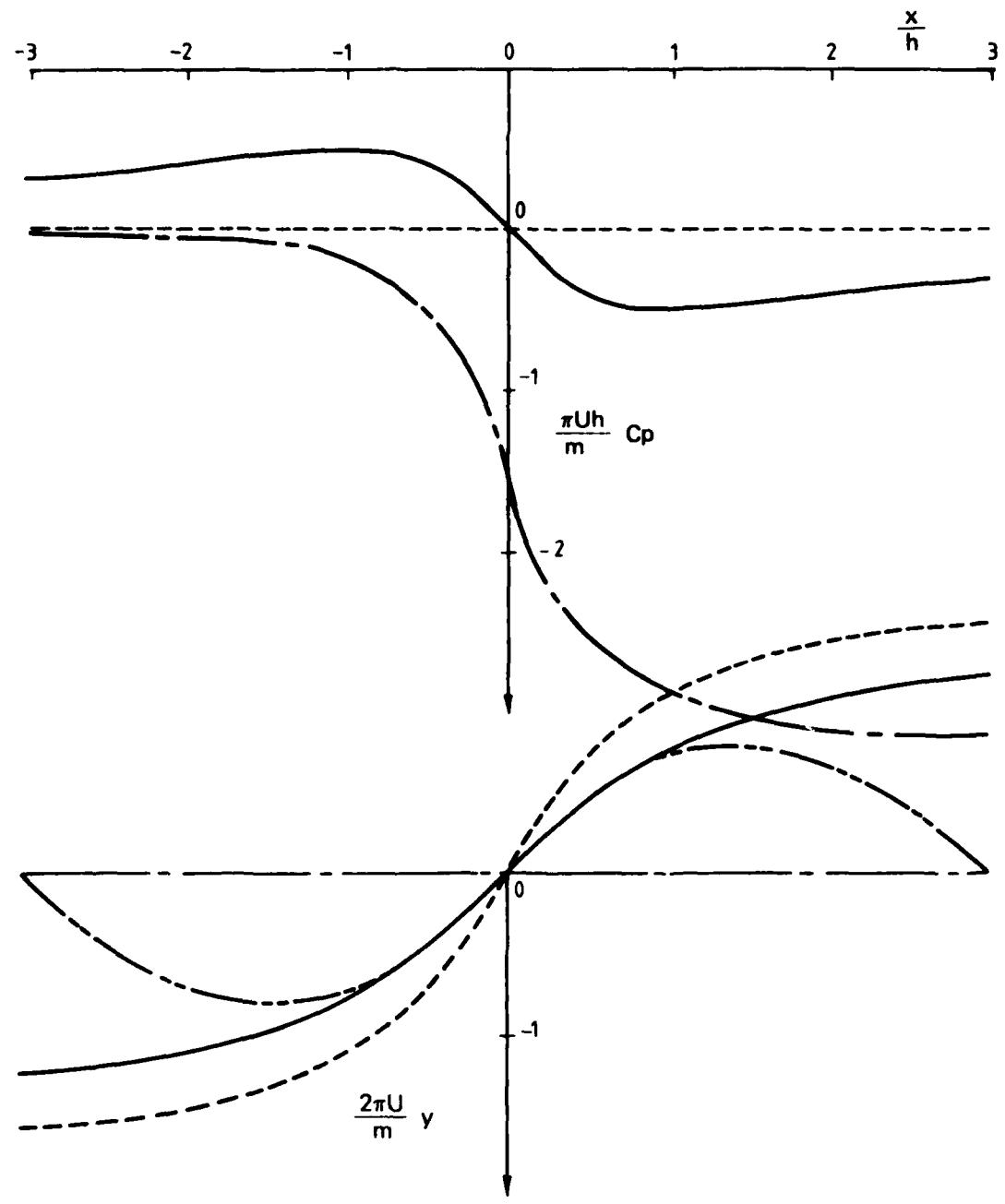


FIG. 2 WALL SHAPES & PRESSURE DISTRIBUTIONS DOUBLET  $M=0$   $\frac{x}{h} = \pm 3$



- Streamline
- - - Conformable wall
- - - Plane wall
- - - Open jet

FIG. 3 WALL SHAPES & PRESSURE DISTRIBUTIONS VORTEX  $M=0$   $\frac{x}{h} = \pm 3$



- Streamline
- - - Conformable wall
- - - Plane wall
- - - - Open jet

FIG. 4 WALL SHAPES & PRESSURE DISTRIBUTIONS SOURCE  $M=0$   $\frac{x}{h} = \pm 3$

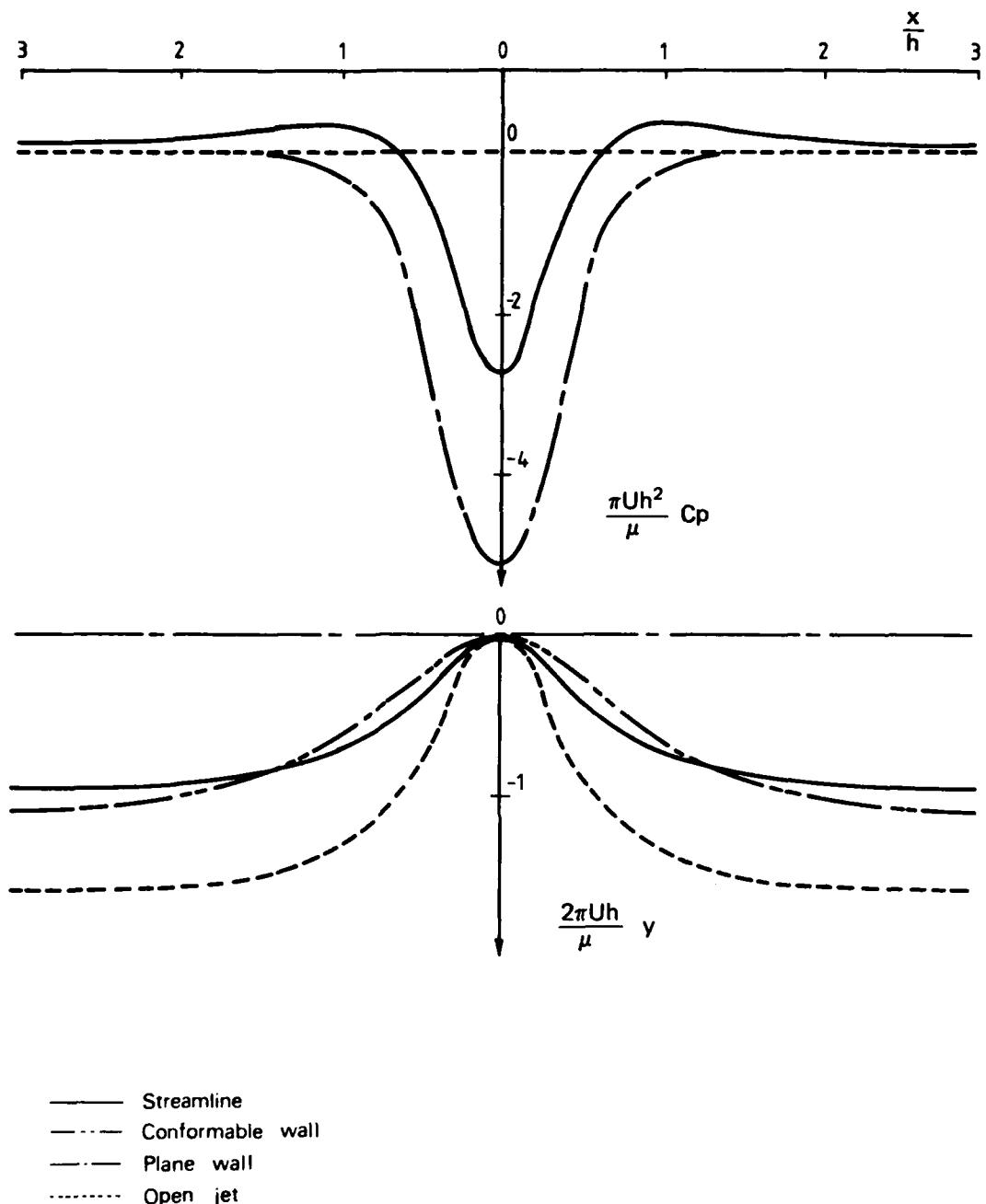


FIG. 5 WALL SHAPES & PRESSURE DISTRIBUTIONS DOUBLET M=0.8  $\frac{x}{h} = \pm 3$

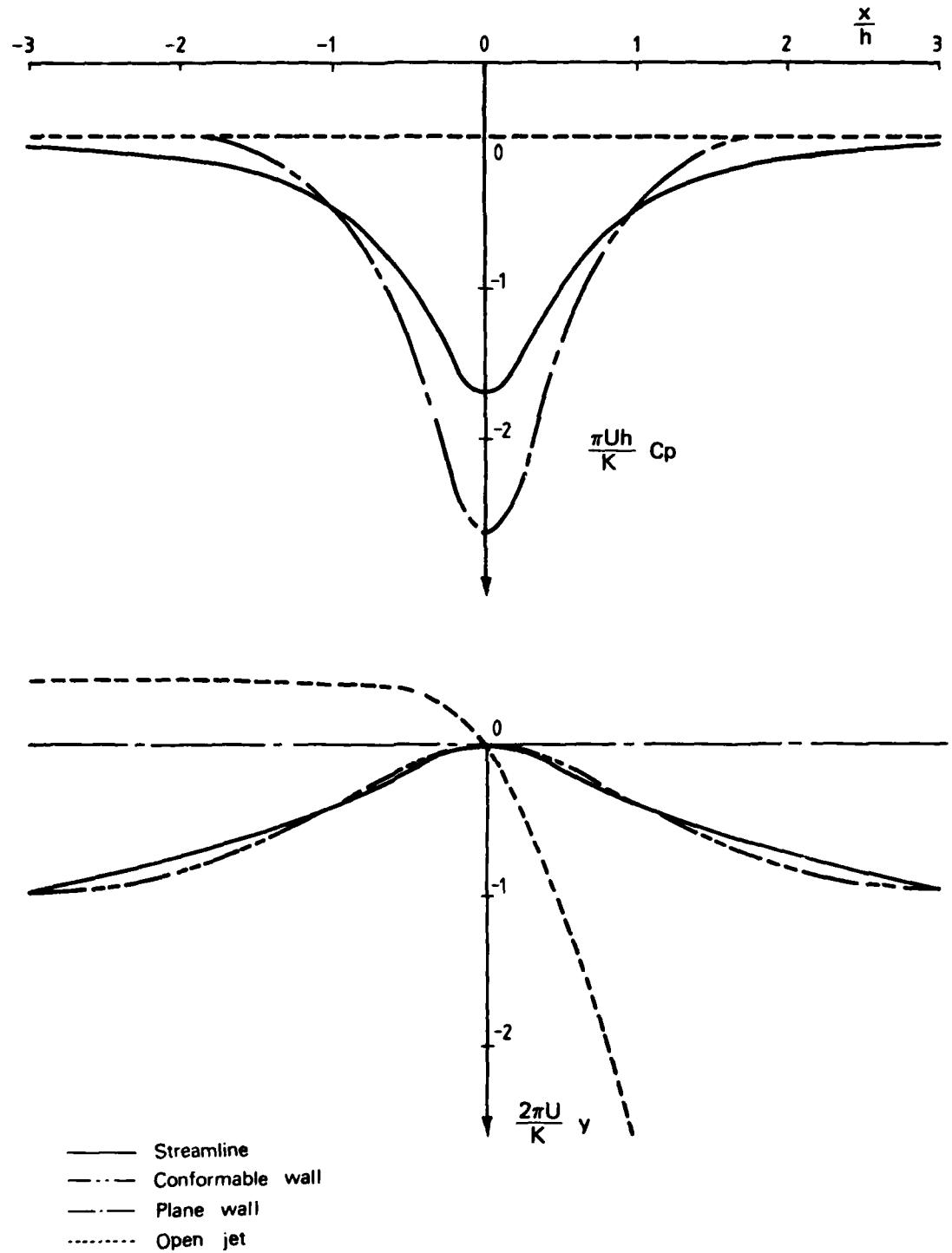


FIG. 6 WALL SHAPES & PRESSURE DISTRIBUTIONS VORTEX  $M=0.8$   $\frac{x}{h} = \pm 3$

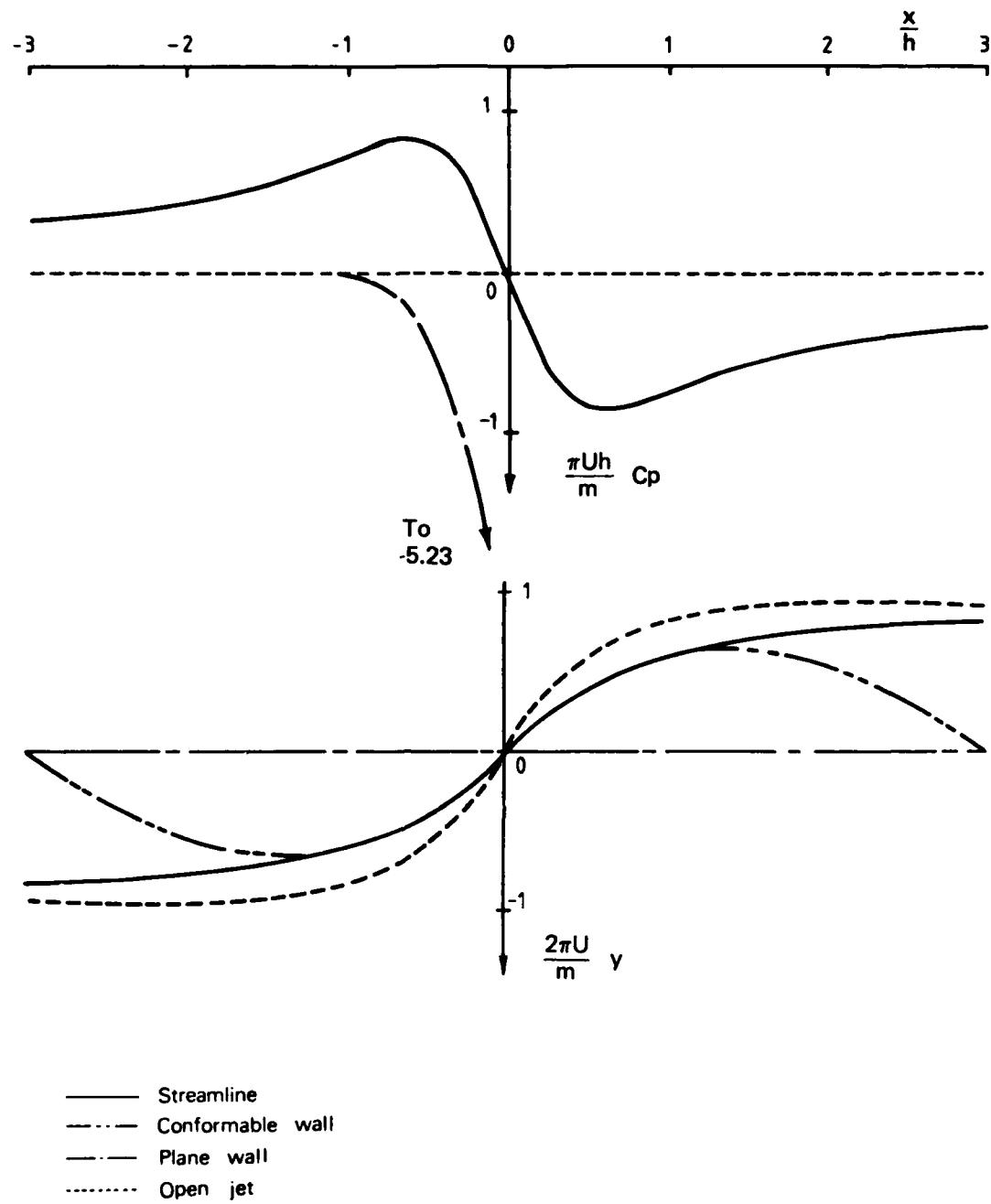


FIG. 7 WALL SHAPES & PRESSURE DISTRIBUTIONS SOURCE M=0.8  $\frac{x}{h} = \pm 3$

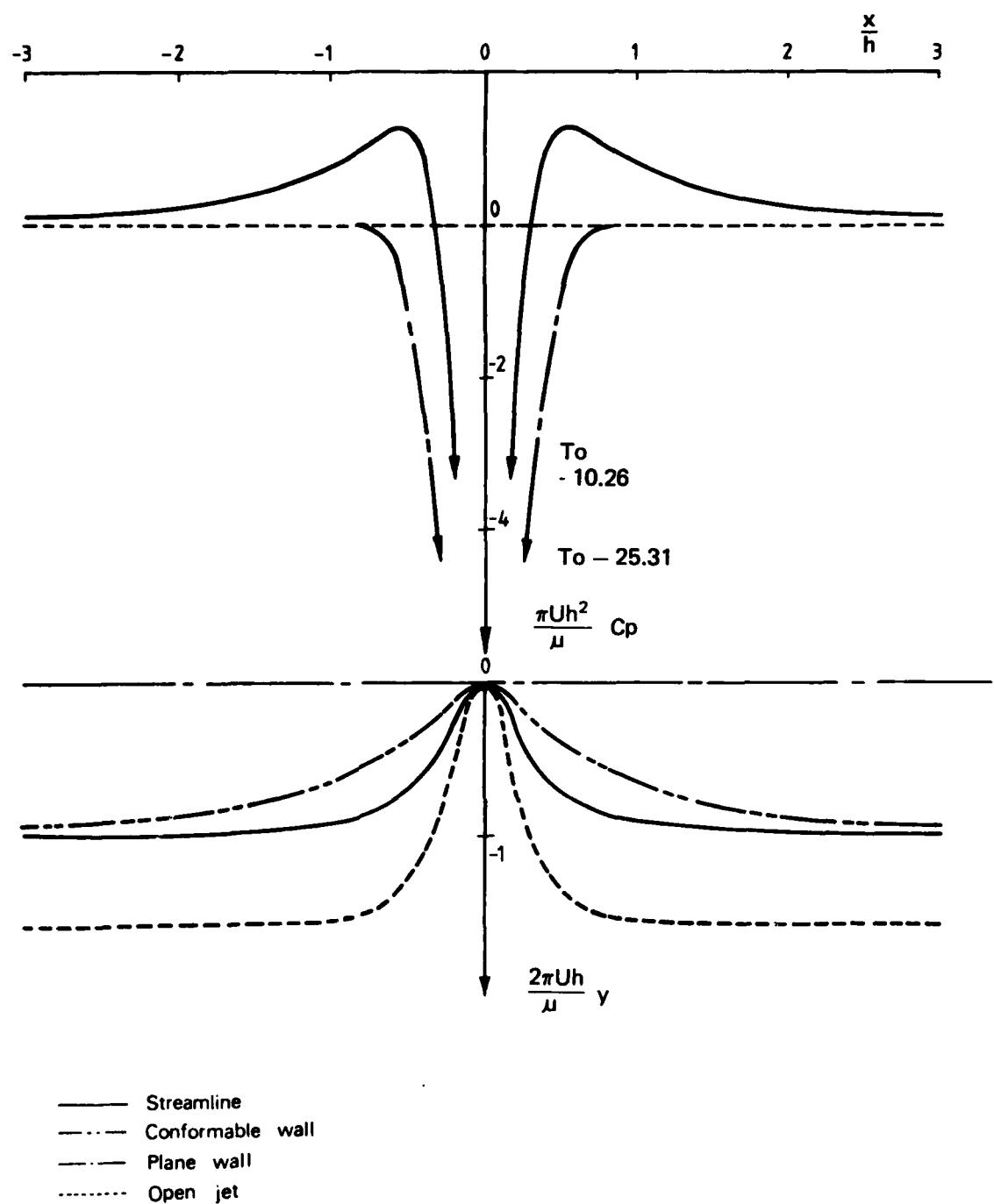


FIG. 8 WALL SHAPES & PRESSURE DISTRIBUTIONS DOUBLET  $M=0.95$   $\frac{x}{h} = \pm 3$

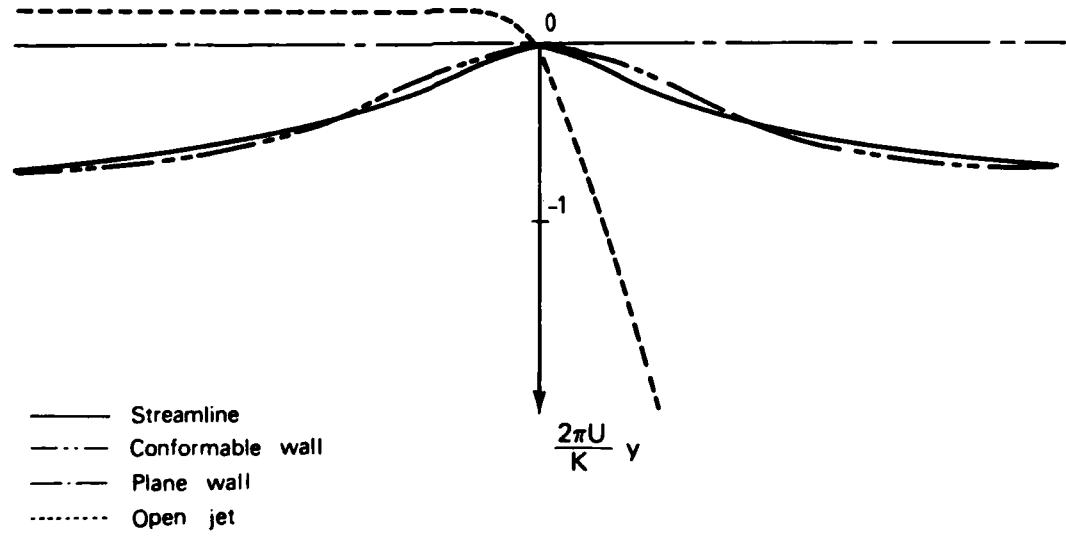
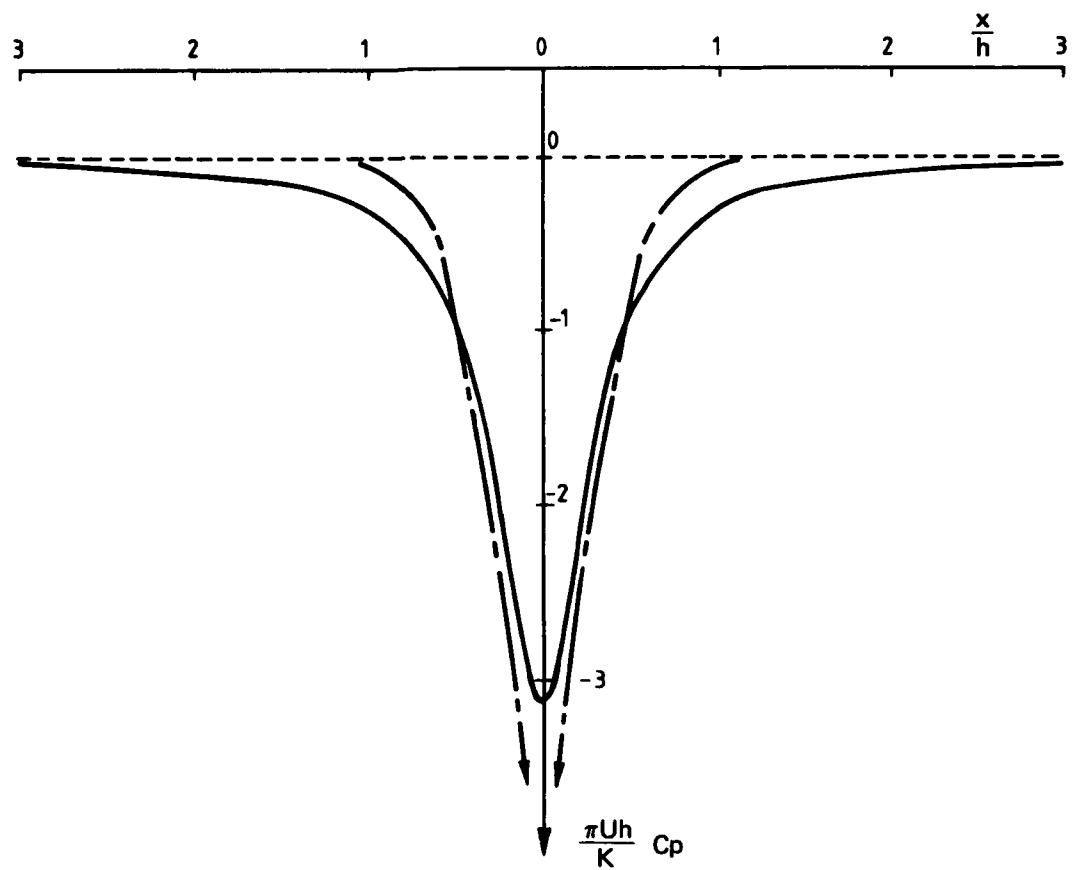


FIG. 9 WALL SHAPES & PRESSURE DISTRIBUTIONS VORTEX  $M=0.95 \frac{x}{h} = \pm 3$

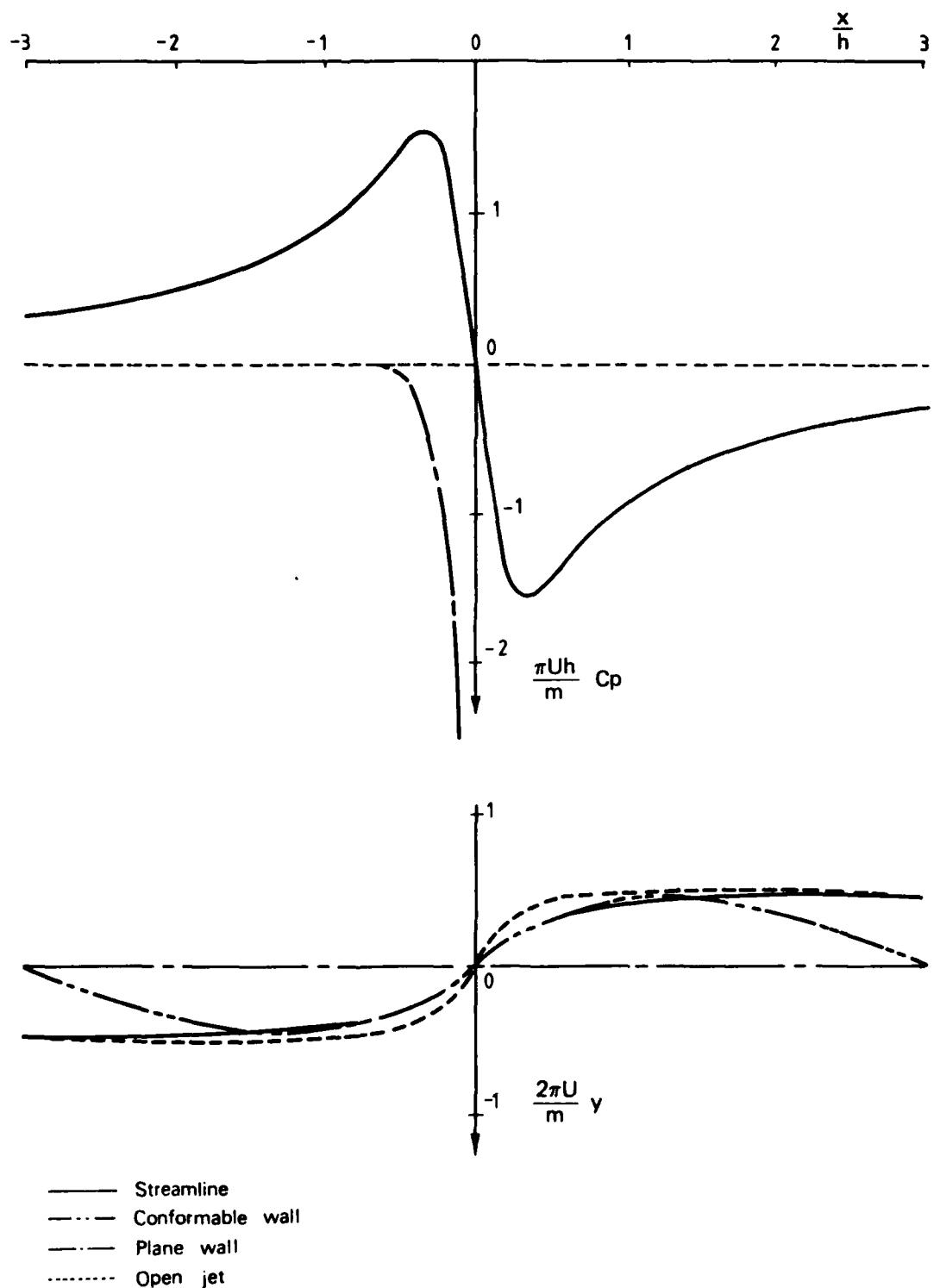


FIG. 10 WALL SHAPES & PRESSURE DISTRIBUTIONS SOURCE  $M=0.95$   $\frac{x}{h} = \pm 3$

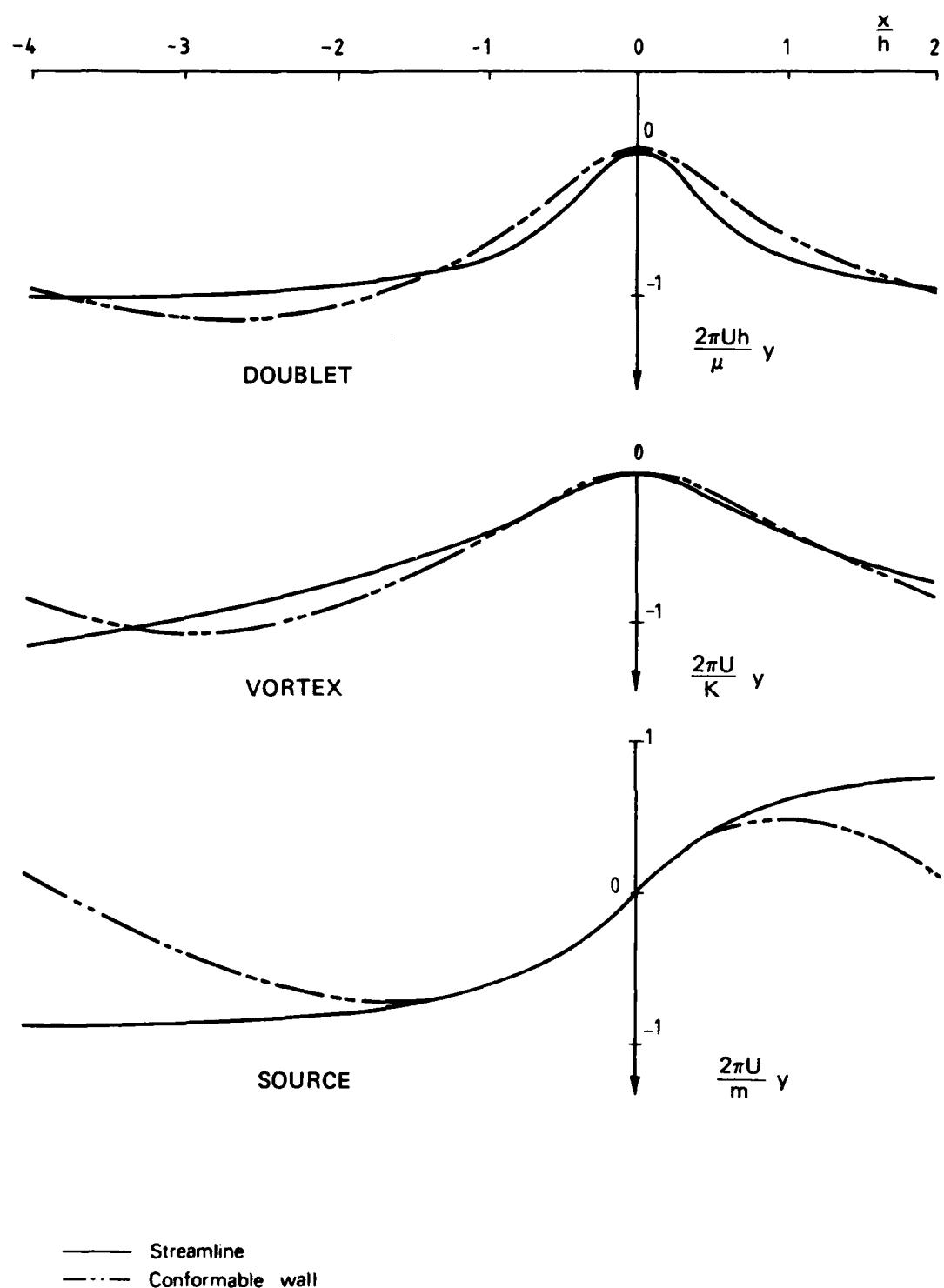
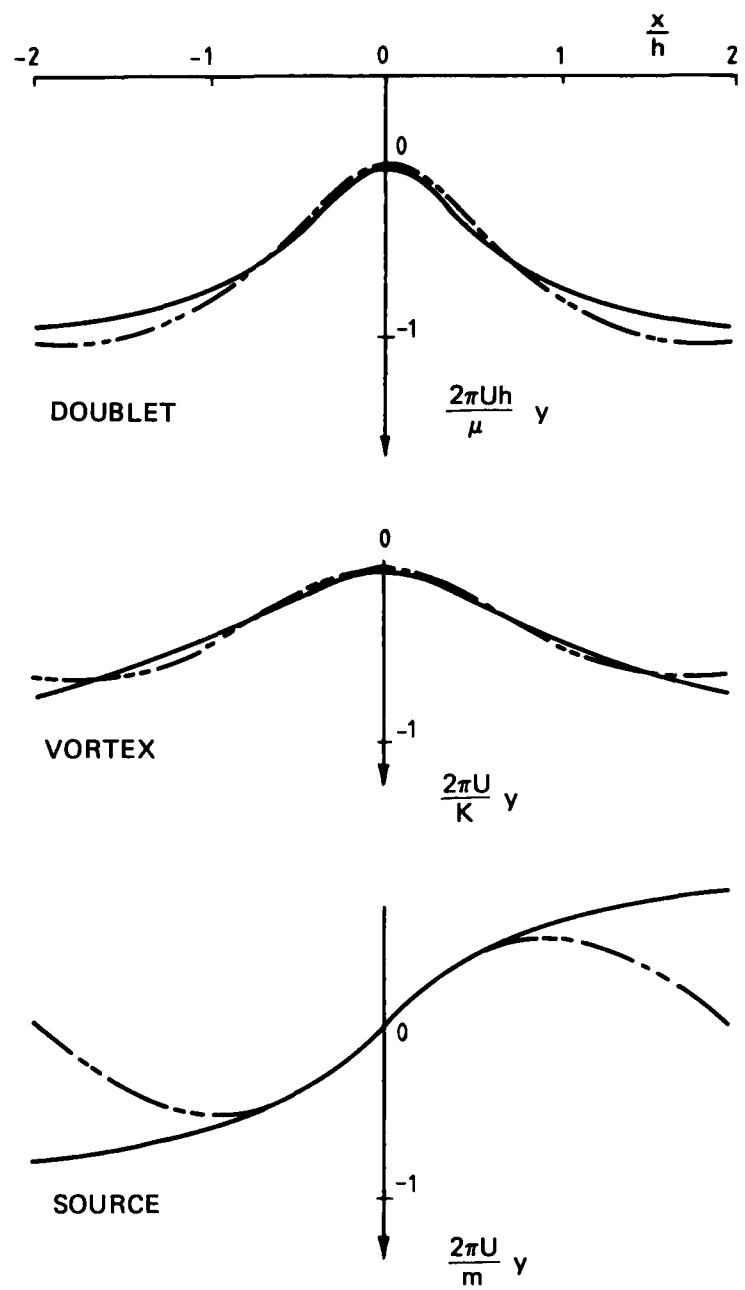
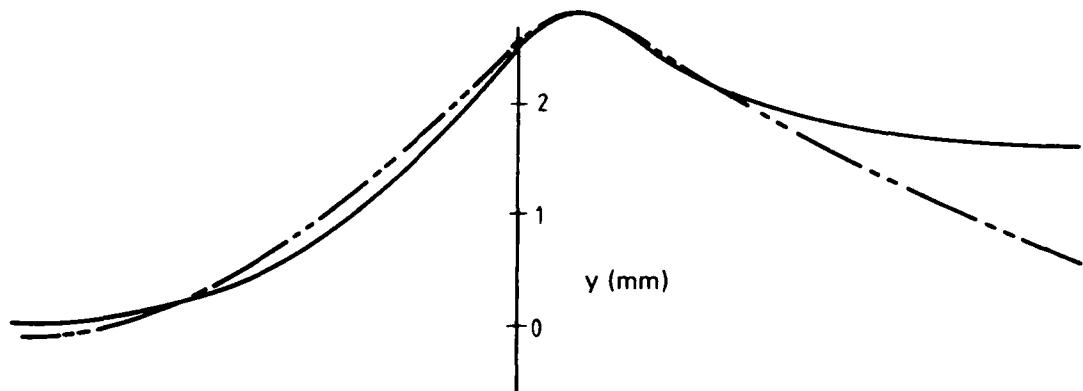
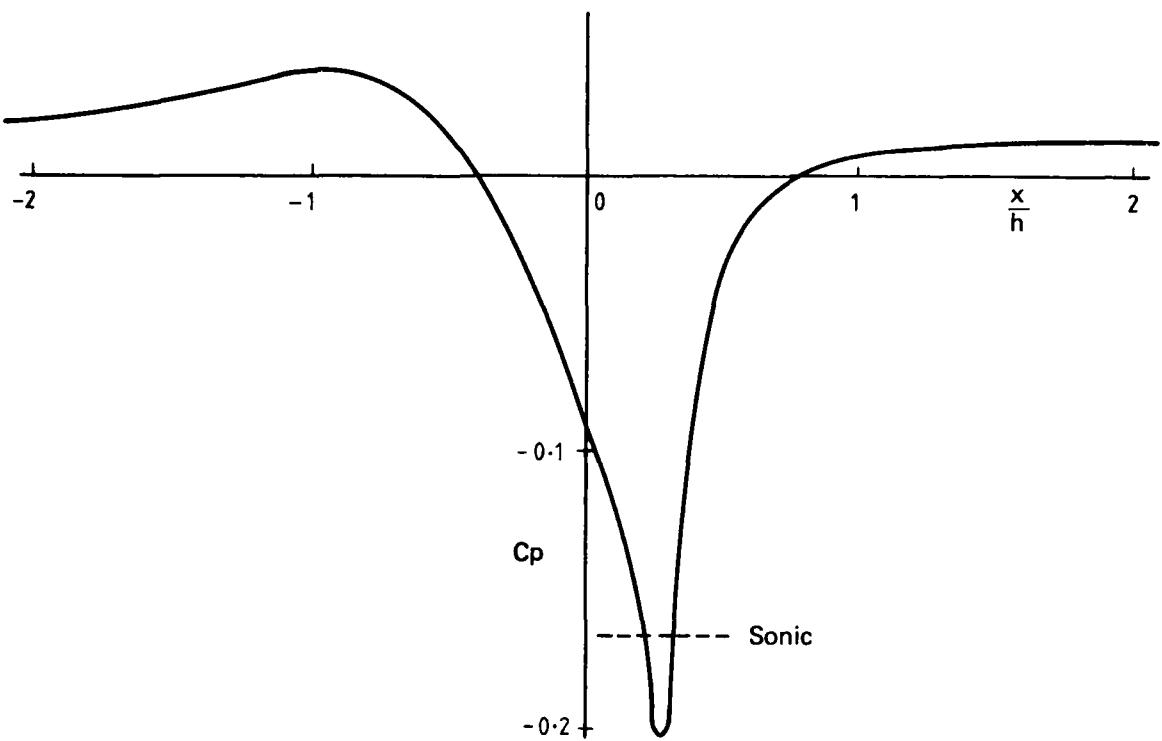


FIG. 11 WALL SHAPES DOUBLET VORTEX AND SOURCE  $M=0.8 \quad \frac{x}{h} = -4 \text{ to } +2$



— Streamline  
- - - Conformable wall

FIG. 12 WALL SHAPES DOUBLET, VORTEX AND SOURCE  $M=0.8 \quad \frac{x}{h} = \pm 2$



— Streamline  
- - - Conformable wall

FIG. 13 WALL SHAPES & PRESSURE DISTRIBUTIONS CIRCULAR ARC AEROFOIL  
127mm CHORD     $M=0.91$      $\frac{x}{h} = \pm 3$      $h = 140\text{mm}$

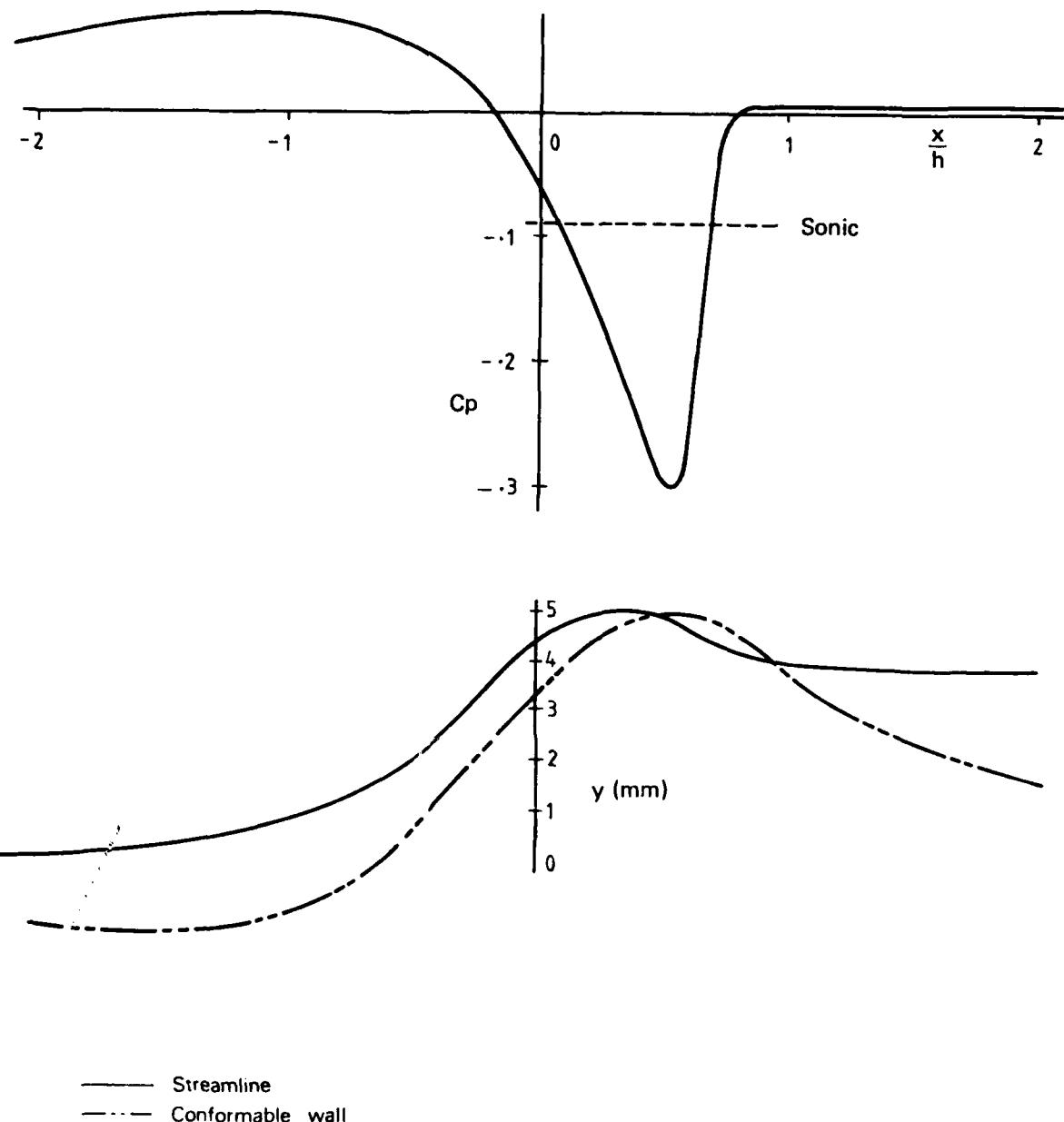


FIG. 14 WALL SHAPES & PRESSURE DISTRIBUTIONS CIRCULAR ARC AEROFOIL  
 127mm CHORD  $M=0.95$   $\frac{x}{h} = \pm 3$   $h=140\text{mm}$

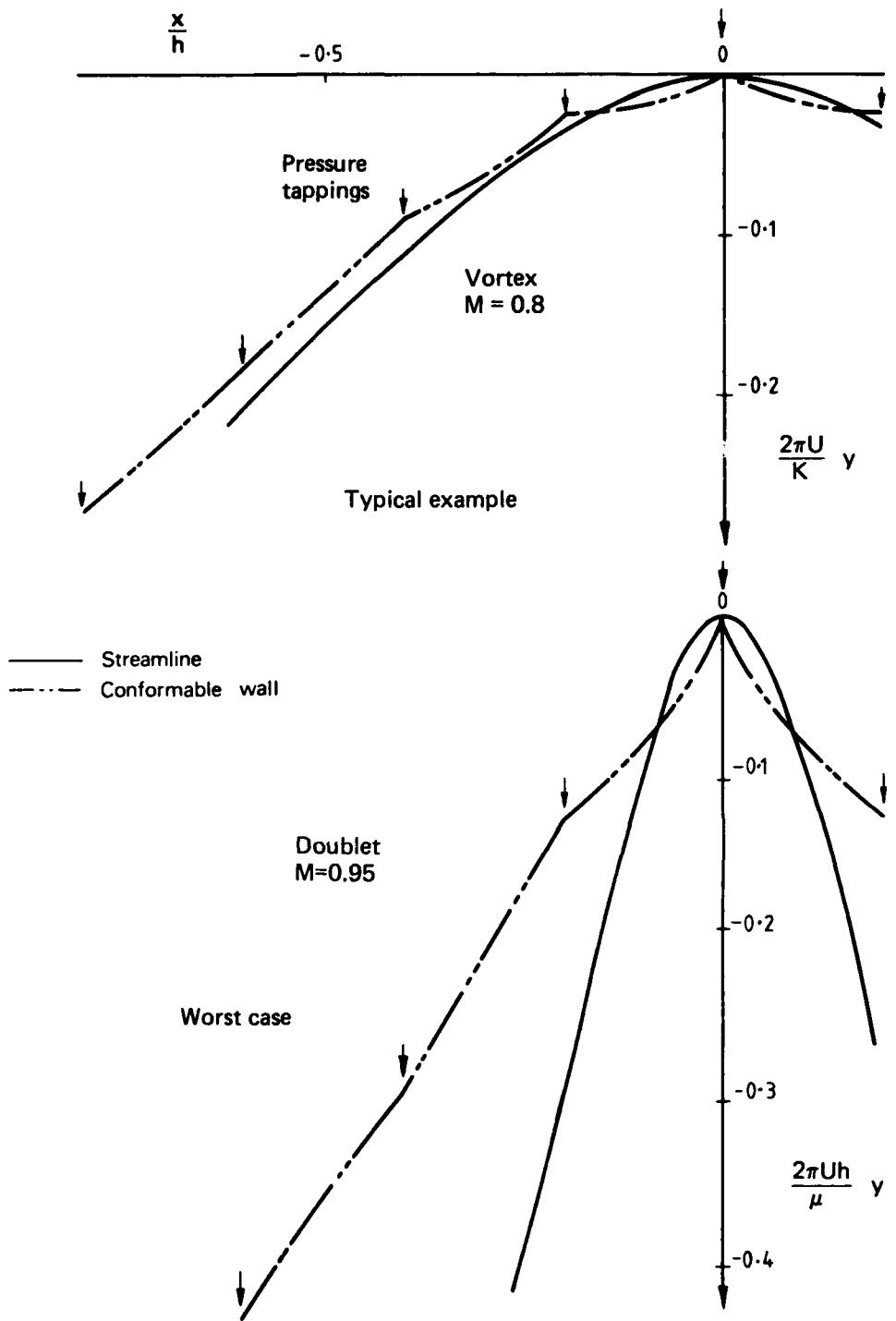


FIG. 15 BULGING BETWEEN PRESSURE TAPPINGS

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